GOVERNMENTAL RESEARCH[1]

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AS an aftermath of war, the past two years have witnessed an unparalleled interest of world wide extent in the subject of scientific research, embracing its aims, scope and methods, as well as its relation to industry, university and government. A remarkable series of contributions and addresses, written mainly by leaders in, or directors of research, have called attention to the various aspects of the subject and have served to inform the public mind and stimulate it to a realization of the importance of research to the community on the one hand and the danger which attends ill considered plans on the other.

One of the most important forums for discussion of this fundamental subject has been the Royal Canadian Institute and I would like to recall, in this connection, particularly, the addresses before this Institute of Dr. George E. Hale on "Co-operation in Research" and Dr. Frank B. Jewett on "Industrial Research." It so happens that Messrs. Hale, Jewett and myself have been identified each with a separate and distinctive phase of the development of research; Dr. Hale with science unalloyed with industrial aspects or governmental control, Dr. Jewett with the applications of science to an industry, and the writer with scientific research in a government department. The preliminary training of each of us was remarkably similar; we are all graduates of the Masschusetts Institute of Technology, specializing in physical science and all had supplementary university training and some teaching experience, since which each has made his life's work in his chosen field of research of the three characteristic types, institutional, industrial, and governmental. We are all therefore exponents of the group method of carrying on research.

As a representative of this third type, that is, of research under government auspices, it may not be without interest to you to have from me a statement regarding the conduct of research in a Government Laboratory. I can of course do no better than give you the impression I have received from the development of the laboratories with which I am associated,

[1] Given at Royal Canadian Institute, April 24, 1920.

those of the Bureau of Standards, and especially in their relation to the public and the government in my own field of metallurgy.

I would first however call to your attention the tendency toward a somewhat different orientation of the relations of government to scientific research in the two countries that are most intimately related in blood and institutions to Canada, namely, Great Britain and the United States.

The relations of the British Government to research are set forth with great completeness in the annual reports of the Committee of the Privy Council for Scientific and Industrial Research and are ably summarized by Sir Frank Heath in an address before the society of Arts on "The Government and the Organization of Scientific Research."[2] The cardinal principles which have guided the development of this trust are set forth in Privy Council Committee's Report of 1918–19 and will bear repeating:

> We believe, in the first place, that while it is possible for the state by means of suitable grants to individuals or the generous support of universities and other independent institutions for research to encourage the pursuit of research in pure science, it is dangerous and even fatal to attempt to organize it. Research of this nature has no other aim than the creation of new knowledge and is impatient of the control which is inseparable from the idea of external organization. On the other hand, it is necessary for the modern State to organize research, including those simpler types of research which we may call investigation into problems which directly affect the well-being of large sections of its people. Such researches and investigation, deal either with applied science or if they are conducted in the realm of pure science are undertaken with a specific end in view. . . .
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> But in the second place, if the organization of research for public purposes is to be effective and economical which will be cognizant of the general lines of research undertaken by different departments of government, and a central body connected therewith capable of undertaking or organizing research which it is agreed can best be conducted by one agency in the interests of all.
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> In the third place, it is dangerous and even fatal under peace conditions for the state to attempt to conduct researches and investigations for the immediate benefit of industries which are not under state management. Industrial research is as integral a part of production or distribution as advertisement or insurance. But this does not preclude the state from encouraging the organization of research within an industry by means of grants-in-aid made under suitable conditions, or even by means of preliminary demonstrations of the valuable results which a well-conducted research may be expected to secure.
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> Finally, it would be fatal to the success of a department entrusted with the encouragement and organization of research to concern itself with exploitation or commercial development or administrative application of the results which may be obtained. . . .

[2] Sir Frank Heath, *Jl. Roy. Arts*, February 21, 1919.

It should be noted also that the English plan separates the administrative functions from the technical or scientific, the policies and progress of the latter being exclusively under the control of advisory committees composed of scientific or technical experts who are not members of the Department.

In the United State, the major branches of scientific research under governmental jurisdiction have not been gathered together under a single administrative head as in England but have been left each to the independent direction of the department of state in which it may be accidentally located, although there is now under consideration a measure that would group all the engineering and many of the scientific bureaus, except those dealing with agriculture, under a single Department of Public Works. The direction of scientific work, as at present organized, is almost exclusively in the hands of scientific men who combine the functions of an administrator and leader in research.

The American plan of independent administrative units does not mean that there are not often very intimate relations between scientific services in the various government departments including interchange of programs, partition of projects between them and other forms of cooperation maintained by a sufficiently close liaison, either formal or informal; although it could hardly be maintained that this common effort is as effective in all cases as could be wished. Again, certain scientific and technical services, such as the Advisory Committee for Aeronautics, are specifically constituted by law to include a membership from the several interested departments and the research work of this Committee is distributed among them. This method of bringing together the representatives of several branches of the service, some dealing with the application and others with the solutions of scientific problems in a definite field of research, makes for better understanding between theory and practice, and the scientific workers have the benefit of valuable advice from the men who are to use the results of the investigation. This constant interplay is beneficial to both. This method of joint research control could be extended with advantage to many other fields of the applications of science in which the government is interested.

One of the most important and fundamental fields of general interest, in which a beginning has been made to bring the departments together, is that of standardization and specifications. It has been proposed to make the Bureau of Standards a clearing house of information—to use the British term—on these subjects for the government. There are great possibilties here

for realizing economies in purchases and improvements in design and there will also result inevitably a considerable impetus to scientific research, especially on fundamental constants and properties of materials which form the basis of constructing standards and writing specifications. The formation of the American Engineering Standards Committee, in which the Departments of Commerce, Navy and War are represented and which is now working in a highly satisfactory manner, forms a further liaison with the public through the Engineering Societies, which again makes for development and improvement in many domains tributary to scientific research.

In looking over the multiplicity of research projects supported by the United States Government, one might easily get the impression that with such a widely scattered responsibility, as actually exists, for the planning of research in the various government departments, there might arise considerable confusion and duplication. A careful survey of the situation, however, would soon convince one of the surprisingly slight amount of overlapping in the scientific work among the several departments. I can speak with some positiveness on this subject as I have been recently occupied in such a survey as a member of the Board which has just completed a study in duplication in scientific work carried on by the government; and it is a fact that actual duplication is almost non-existent.

Although there are in the United States for certain lines of governmental scientific research, such formal or informal advisory technical committees as mentioned above, the rôle of initiation, correlation and stimulation of research, including industrial scientific research, taken in England by the Department of Scientific and Industrial Research, has been, in the United States, largely assumed within the past year or two by the National Research Council, the organization and scope of which has been so ably set forth before this Institute by its first Chairman, Dr. Hale.

The impetus given in England by the Government to the organization and support of Research Associations has been, it seems to me, one of the most remarkable of recent achievements in the successful intervention by a government for the encouragement of national industries by aiding in the formation of a type of organization by which the industries can best help themselves. The crucial test of this method of stimulating industrial research will in all probability come after the five years time limit of government support is reached when the Research Associations will have to shift for themselves.

The Research Council has been endeavoring to foster in the

United States the formation of somewhat similar cooperative scientific research associations among several of the American industries, but to this date, it would appear safe to say, with but indifferent success. It is perhaps, not too early to ask, why does the formation of such Research Associations readily succeed in Great Britain and apparently not in the United States? Is it because of government initiative and support that they are established so promptly in England and would they be eventually in the United States if such support were forthcoming? Is it, that in the United States the industries are already provided with all the research assistance they need or can make use of? Or, on the other hand, can it be argued our industrial leaders are not yet convinced of the value of this type of cooperative research? I do not venture to answer these questions, replies to which in the last analysis may be but a formulation of underlying national characteristics; but possibly you in Canada by your solution of the problem will help shed light that will aid us all.

What has been the policy of the Government of the United States toward scientific research and its applications to the industries of the country? To put the question is to call forth immediately, what is familiar to you all, the response that in many fields, notably in the agricultural sciences, the Government has been the most generous of sponsors. It is also supporting research in almost all domains of pure and applied science from astronomy and mathematics to metallurgy and road construction, and in many other branches than agricultural research it has been the pioneer and still is the leader. Moreover, in recent years, there has been a marked advance in governmental support of scientific research fundamental to industry, particularly as exemplified by the Bureau of Mines and of Standards.

So much has been written recently about the advantages, including atmosphere, surroundings and status of research conducted under university or institutional guidance on the one hand and in industrial establishments on the other hand, and so little has been said—and silence may appear to be more eloquent than speech under certain conditions—of the advantages of research under governmental auspices, that it is difficult to resist setting forth here some of the conditions, as I see them, of research in a government department and of the position of the scientific men in the government service.

If government service, which we must remember is service for the public, is so unattractive, as certain writers have intimated, why for instance has the senior scientific staff of the Bureau of Standards remained nearly intact from its founda-

tion nearly twenty years ago? There must be some other than pecuniary advantages to account for this stability of position among scientific leaders, which has been the rule, rather than the exception, until very recently in most of the scientific establishments of the American government. The present moment, marked by scientific men leaving the government in unprecedented numbers, may be accounted for primarily by the bidding for their services by industries and institutions that have been able to readjust their salary scales to meet the mounting cost of living more promptly than had the government. It is within reason to suppose however that this situation will be eventually readjusted.

What then are some of the advantages to the scientific man of his position in the government service as compared with the university man or the man in a research laboratory pertaining to industry, The attributes the research worker most cherishes are freedom for development within his chosen field; unhampered opportunity to publish the results of his discoveries; the stimulation afforded by the congenial atmosphere of sympathetic and critical co-workers; an absence of extraneous, irksome tasks; in the existence and maintenance of the ever changing material facilities for research. Taking the Bureau of Standards as a type of governmental institution devoted largely to scientific research, I can state from experience I know of no other type where these desirable attributes are more happily blended than here.

There is also the added satisfaction, or privilege if you will, the "government scientist" possesses, in that he is conscious of working directly for the public welfare in response to a public demand, expressed through the representatives of the people in Congress by their allotment of funds to support his work. This direct relation to the public—and it is much more intimate than many persons realize—gives him a pride and confidence in his accomplishments that cannot be had by any one working solely for himself and his science or for an industry or commercial firm. His sense of responsibility is enhanced and he will plan his work accordingly. As he demonstrates his ability to make efficient use of it, his freedom of choice of subjects is almost unlimited, and he has absolute liberty as to his methods of attacking the problems he sets out to solve. I wonder if more can be said for any other type of research center?

The craving to communicate his ideas and exhibit his work to others is a well-known trait of the scientific man. Among the hundreds, nay thousands of investigators in the industrial research laboratories the ideals of which have been outlined by

Messrs. Jewett, Mees,[3] Carty, Nutting, how many of these men have the opportunity of free communion with others? On all important problems—important from the technical, competitive point of view—absolute silence is usually the most rigid of pass words. What might become many able contributions to science never see the light of day, on account of, what appears to me, a misguided policy of secrecy which often extends to unessentials, from the manufacturer's point of view, in an industrial research laboratory. The following is an illustration among many: the director of a long-established industrial research laboratory showed me the other day the reports on a series of long since completed but as yet unpublished investigation of considerable general interest, two of which had just been duplicated and published by the Bureau of Standards where we had no knowledge of the previous work. In addition to the economic waste of unnecessary duplication, what is the effect on the morale of the men who did the work first and had it suppressed except for use in the plant?

The benefits of association and working in a community of considerable size where there may be rapid interchange and immediate availability of information and experimental facilities are often overlooked by those who advocate the advantages of research by lone individuals in the conditions of practical isolation often prevailing in even our larger universities. The laboratories of the government, and to a less extent the larger industrial laboratories, should be and unquestionably are able to secure more rapid progress and greater effectiveness in the execution of research than can the isolated worker.

Then as to the facilities or tools of research, the public laboratories, speaking generally, are better equipped than most private laboratories, although some of the industries maintain laboratories before which even the government laboratories pale. The industrial research laboratories to be effective must also possess as adjuncts development laboratories for manufacturing on an experimental scale. In pure science there are many problems, often the most fundamental such as the exact determination of physical constants and standards, which require very elaborate and costly layouts and often take a series of years for their completion. Such can best be left to the government laboratories.

It would thus appear that viewed from these various standpoints of freedom, publication, facilities, atmosphere, so dear to

[3] C. L. K. Mees, "The Organization of Industrial Scientific Research," McGraw Hill, 1920, contains an excellent bibliography of recent titles.

the research worker he is at least as well off in the government laboratory as elsewhere.

As an example of the operation of a government research laboratory in the United States, let us take the Division of Metallurgy of the Bureau of Standards. What does it do and how?

First as to organization; the Bureau is divided for administrative convenience into twelve divisions, the office, the plant, the shops, and nine scientific or technical divisions, each constituting one of the branches of scientific work carried out at the Bureau, electricity, optics, heat, chemistry, weights and measures, metallurgy, engineering physics, structural materials, ceramics. Each division is again divided into sections; thus in metallurgy there are sections of: (1) Microscopy and Structure of Metals, (2) Heat Treatment and Thermal Analysis, (3) Working and Miscellaneous Properties, (4) Chemical Metallurgy, (5) Foundry.

The methods of directing and conducting the research work within the division we may mention briefly. There are no rules and regulations. Funds are allotted to the Division either by direct appropriation of Congress for a specific purpose or from the general funds of the Bureau by the director. Each research is authorized by the director on the written advice of the division chief. At meetings of the leaders within the division the program of work is considered and as a result of these discussions supplemented by written estimates the divisional budget is made up. Frequent conferences of the leaders are held to determine questions of policy and the progress of the work is fully discussed. Occasional meetings of the separate sections are also held, and there are also constantly being held informal conferences of members of the staff interested in any problem. The whole Division meets once in two weeks when a formal presentation of some investigation is given by its author. Each member of the Division presents a monthly progress report in writing. The papers offered for publication are reviewed critically by a committee of experts within the Bureau. A personnel committee consisting of all chiefs of divisions passes on most promotions.

The supervision of the routine work of testing and standardization is carried out by the leaders in research covering the same subject. There may or may not be a distinction between the personnel engaged in testing and research depending upon circumstances. This arrangement makes for flexibility, and avoids indivious distinctions and has worked extremely well. Men showing an aptitude for research have the oppor-

tunity to show it even if they may be assigned originally to routine work, and conversely. The skeleton of the organization is however of little importance as compared with its spirit. The Bureau of Standards consists above all of men and women imbued with high ideals and is a living organism of the highest type.

The Division of Metallurgy was formed in July, 1913, and has grown in population from one to fifty-seven and has acquired a very complete equipment to meet the needs of metallurgical research and testing. Over the development of testing we have no immediate control. The public and the government departments send us what they will and we try to satisfy their demands. It is a remarkable fact worthy of note that whenever a new line of testing is announced, immediately there is set up a never-ceasing flow of materials or instruments for test, the volume of which is oftentimes embarrassing; and in consequence one of our most difficult problems is to adjust equitably our efforts as between the execution of tests, our routine work, and the carrying out of investigations, our preferred work of at least equal urgency. There is here of course the ever present danger of too easily choosing the immediate for the permanent. Although not so vociferously expressed the real demand for knowledge concerning fundamental constants and properties is at least as great as the need expressed in the polite but insistent requests for the report on a trivial test of a material of interest to but one party. We are obliged to remind ourselves at times that we are here to serve the best interests of the public in our several domains of science.

The field covered by our metallurgical researches and investigations embraces subjects confined mainly to what has been called products metallurgy as distinguished from what is called process metallurgy which latter is illustrated by the reduction of metals from their ores, the field of the Bureau of Mines.

As one of the subjects of metallurgical research which will undoubtedly have far-reaching consequences, mention may be made of the study of gases in steel, including the development of methods of analysis; the determination of the quantity and manner on inclusion of the several gases which may be present such as oxygen, nitrogen, hydrogen and the oxides of carbon; and the characteristic gas content for steels of different composition and as determined by the method of manufacture. An immediate application of the methods here employed has been developed in our investigation of steel welding methods and products. The clearing up of the behavior of welded metals as

influenced by its gas content will aid greatly in solving some of the difficult problems connected with the welding art.

We were greatly concerned during the war with the scarcity, real or threatened, of several minerals and metals of vital necessity to the industries of the country. Among these were manganese, tin and platinum, and it became necessary to modify manufacturing process and devise suitable substitutes. We did a great deal of research work along these lines. Thus in the case of tin, for example, which is all imported, we developed a satisfactory solder containing only ten per cent. of tin instead of the usual 40 or 50 per cent. This solder containing also 80 per cent. lead and 10 per cent. cadnium was as cheap as ordinary solder. The tin content of bearing metals for most uses, it was shown, could be very greatly reduced; and for the tin bronzes satisfactory alloys, if made of available metals, were substituted. In fact, I believe America could have carried on with some ten per cent. of the normal tin consumption.

A great deal of attention is given constantly to questions connected with the various types of failure of metals and metal products such as flaky steel and internal fissures, railroad materials and stress corrosion in structural bronzes, to mention but two types, and numerous papers on these subjects have been published by the staff. The various and puzzling aspects of the corrosion of metals also requires constant attention.

There is now under way a series of investigations on special steels including structural steels, high speed steels, and their substitutes, high chromium steels of various types, and of steels containing unusual elements.

Some of the other subjects of metallurgical research are copper crushes guages for testing powder, improvement of machine gun barrels to resist erosion, identification tags for the Army and Navy, spark plug electrodes, characteristics of bearing metals, metals for aeronautical instruments, centrifugal steel castings, comparison of ingot practice in steel manufacture, temperature control of metallurgical manufacturing operations, embrittling of the steel parts by cleaning, pickling and plating, standard test bars for various alloys, and many other matters.

I shall not tire you, however, with an enumeration, much less with a description, of each of the seventy odd research problems in metallurgy with which we are occupied. They may be found in summary form from year to year in the annual reports of the director and appear in detail as they are completed in the publications of the Bureau and the scientific press. I may mention, however, some of the broad lines along which we

are orienting our work and in doing so will endeavor to emphasize the cooperative aspects of this research work, for much of it is undertaken after consultation or in active participation with other groups having also an interest or a part in its accomplishment.

This cooperation in research takes several forms and is of various types; thus there may be one or more of the other departments of the government interested in the prosecution of a research in which we also have an interest. For example, there has been carried out an investigation of considerable magnitude on the development and properties of a series of special steels with a view to their serviceability for light armor; in that research the Bureaus of Mines, Standards and Navy Ordnance have participated. Again, in consultation with the Advisory Committee for Aeronautics a series of researches on light aluminum alloys have been carried out. For the Army Ordnance, and sometimes in cooperation with that establishment, a whole series of investigations have been executed or are still under way. The list of interdepartmental cooperative researches in metallurgy is of quite considerable length, but the above illustrations may suffice to show that to secure scientific coordination among the government departments a central body is not indispensable.

Turning now to our cooperative relations with non-governmental bodies our relations with some of the scientific and technical societies are very close. Thus the work of the American Society for Testing Materials is largely participated in by the Bureau and particularly in Metallurgy our work has often been oriented to meet the desires of the various technical committees which are planning important lines of research of interest to science and industry; for example, coated metals, corrosion of iron and steel, the standardization of ladle test ingots in steel making.

With the National Research Council and its several committees on metallurgical matters we are in most active cooperation; I need but mention the work of the Pyrometer Committee and the extraordinarily successful symposium on pyrometry held at the meeting last fall of the American Institute of Mining and Metallurgical Engineers.

There is still another type of cooperation that should be mentioned, namely, the solving in the government laboratory of some of the problems fundamental to manufacturing processes and standards which are of interest to an industry as a whole. The development of this type of cooperative industrial research is still in its infancy in the United States, and evidently requires

an experimental manufacturing plant for each type of industry. We have made some provision for this field of development in metallurgy by installing several operating or semi-manufacturing units which, on a quarter ton basis, will allow us to make any metal or alloy, submit it to various heat treatments, shape and work it by rolling, forging, or drawing.

I should like, before closing, to call your attention to a co-operative research of the greatest economic importance, conceived on a somewhat more comprehensive scale than anything else we have hitherto undertaken; I refer to the investigation just gotten under way under the auspices of a Joint Committee to study the effects of sulphur and phosphorous in steel and in the specifications for the various grades of steel. This is a subject about which there is a great deal of diverse opinion and the experimental results published thus far have not been considered of sufficient weight to justify changing the present and long accepted values of sulphur and phosphorous contents in steel by responsible specification making bodies.

The Joint Committee, the chairmanship of which is held by the Bureau of Standards, is constituted with representatives of the government including the Departments of Commerce, War and Navy, steel makers, and specification making bodies including the American Society for Testing Materials, the railroads, the automotive and shipping industries. It is hoped, in view of the fact that the program of tests is mapped out by unanimous agreement of all interested parties; the steel manufacture witnessed by representatives of all interests; and the tests carried out in government laboratories, that the results of this elaborate research will be determinative as to revision of the specifications in question.

With this summary review of a few of the aspects of governmental research, as I see them, and as illustrated specifically in the work in Metallurgy at the Bureau of Standards, I trust you will carry away the impression, which I have endeavored to convey, that there is a human side to research and that in the government service it is possible to be very close to the public, in fact a part of the public and not a group set apart to solve abstruse problems of little general interest. I believe it not only desirable but absolutely essential that a government laboratory, and by that term I mean the men who work in it, keep in closest possible touch with the professional as well as the non-technical public it serves and that a crucial test of the usefulness of such a laboratory is the interest and above all the confidence it inspires.